Appendix AB

Appendix AB - Fischer, D.L. 1986. Daily Activity Patterns and Habitat Use of Coexisting Accipiter Hawks in Utah. Manuscripts of Journal Articles, Department of Zoology, Brigham Young University.

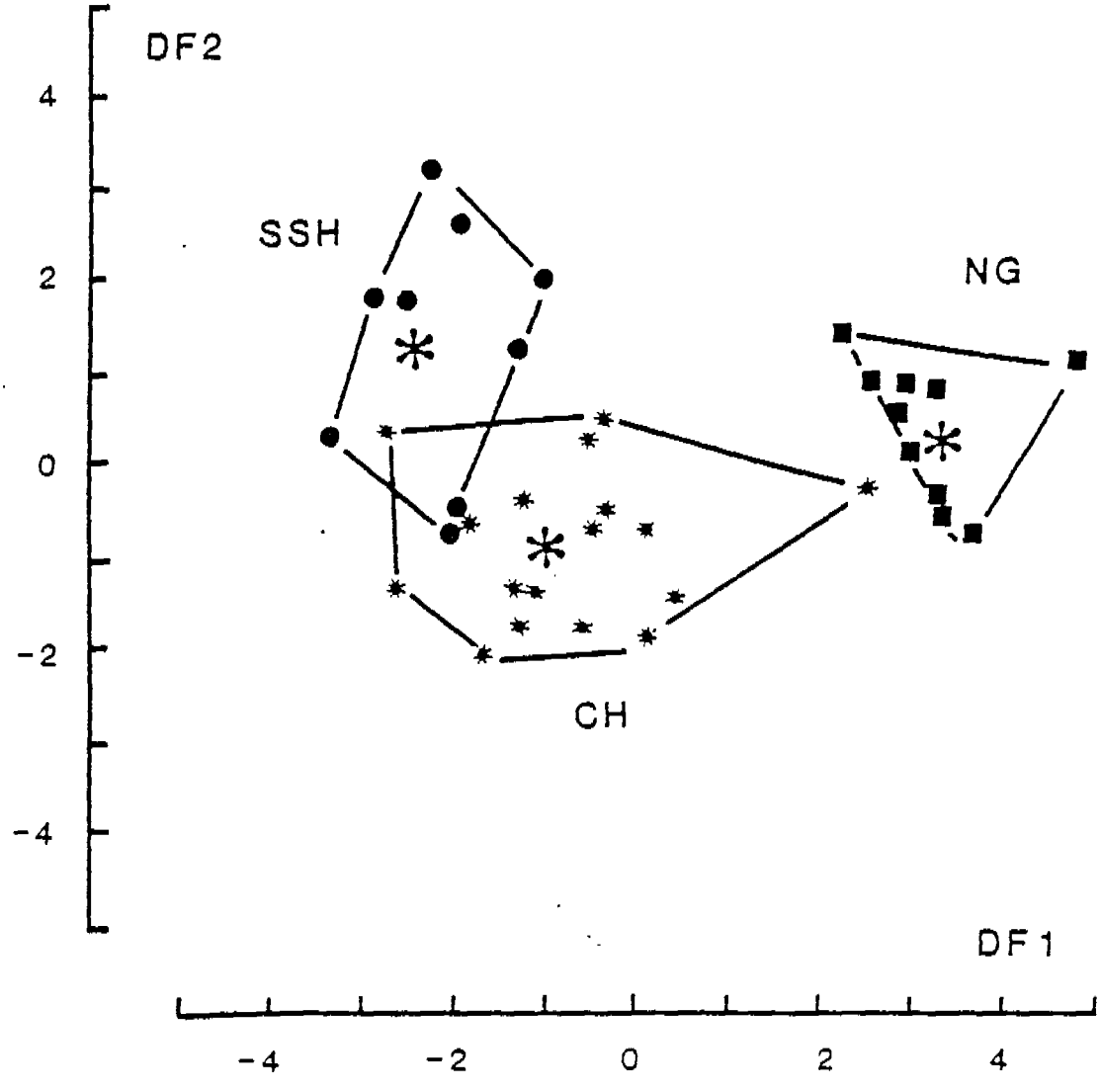
DAILY ACTIVITY PATTERNS AND HABITAT USE OF COEXISTING *ACCIPITER* HAWKS IN UTAH

Manuscripts of Journal Articles
Presented to the Department of Zoology
Brigham Young University

In Partial Fulfillment of
the Requirements for the Degree
Doctor of Philosophy

by
David Lawrence Fischer

April 1986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David L. Fischer
Department of Zoology
Brigham Young University
Provo, UT 84602

FORAGING AND NESTING HABITAT OF *ACCIPITER* HAWKS IN UTAH

running head: *ACCIPITER* HABITAT IN UTAH

DAVID L. FISCHER, Department of Zoology, Brigham Young University, Provo, Utah 84602.

JOSEPH R. MURPHY, Department of Zoology, Brigham Young University, Provo, Utah 84602

Abstract: Foraging and nesting habitat of three coexisting species of *Accipiter*, the Northern Goshawk (*A. gentilis*), Cooper's Hawk (*A. cooperii*) and Sharp-shinned Hawk (*A. striatus*), was investigated in central Utah. Sharp-shinned Hawks foraged in all habitat types present in their home ranges, while Cooper's Hawks and Northern Goshawks foraged preferentially in certain forest types, and avoided others. Northern Goshawks preferred woodland with large, mature trees. Cooper's Hawks preferred denser stands of small to medium-sized trees. Species differences in use of habitat for foraging related more to differences in accessability, than to interspecific avoidance. Nesting habitat of all three species was distinct. Sharp-shinned Hawks nested in the shortest and densest woods; Northern Goshawks nested in the tallest and most open woods; Cooper's Hawks nested in intermediate woodland. It is suggested that interspecific differences in nesting sites is better explained by

predation pressures, than by competition.

Key Words: Accipiter gentilis, A. cooperii, A. striatus, Northern Goshawk, Cooper's Hawk, Sharp-shinned Hawk, Nesting Habitat, Foraging Habitat, Habitat Partitioning, Radio-telemetry.

Effective management of any wildlife species requires precise knowledge of habitat requirements. For raptors, habitat management efforts have most often been directed toward identifying, protecting and enhancing nesting sites and foraging areas (Olendorff et al. 1980).

Foraging habitat has usually been investigated on a coarse-grain level (i.e., the level of the biological community). Number of observations made or time spent in broad habitat categories such as "woodland", "agricultural land" or "desert scrub", have been reported for many raptor species (Fischer et al. 1984, and references therein). Rarely, the specific microhabitats associated with hunting perches or prey capture sites have been described (Steenhof et al. 1980, Kenward 1982). Because of convenience, studies have usually been carried out on species that are diurnal, live in open country and choose conspicuous perches (e.g. Ferruginous Hawk, Wakely 1978). Radio-telemetry methods provide a means of obtaining similar data in species less easily observed such as owls (Nichols and Warner 1972, Fuller 1979) and accipiters (Kenward 1982).

Nesting habitat of raptors has been investigated on a finer-grained level. Recent studies have used a multivariate approach to describe the microhabitats of nest sites (Titus and Mosher 1981). In Buteo (Schmutz et al. 1980, Titus and Mosher 1981, Janes 1985) and Accipiter (Hennessy 1978, Reynolds et al. 1982, Moore and Henny 1983), coexisting congeners select distinct microhabits, suggesting that partitioning of nesting habitat between closely related species is usual.

From 1982-1985, we investigated habitat used for foraging and nesting in central Utah by the three North American species of Accipiter: the Northern Goshawk (A. gentilis), Cooper's Hawk (A. cooperii) and Sharp-shinned Hawk (A. striatus). Relative use of six habitat types by foraging accipiters was investigated by radio-tracking breeding adults during the nestling and fledgling-dependency periods. At this time, energy demands of young force adults to devote considerable time to hunting. Nesting habitat was studied by using a multivariate approach similar to Titus and Mosher (1981) and Reynolds et al. (1982). Previous studies investigated food partitioning between species and/or sexes of this assemblage (Storer 1966, Reynolds 1979, Kennedy 1981, Reynolds and Meslow 1984), but it was not known if differences existed between species or sexes in habitat used for foraging. Hennessy (1978), Reynolds et al. (1982) and Moore and Henny (1983) quantified nesting habitat of these three species in northern Utah, southern Idaho and Oregon, but their data come from areas dominated by coniferous forests. Our study area was predominantely deciduous forest. Whenever possible,

we tested the null hypotheses that no differences in habitat use existed between species, and that use of specific habitat types was proportional to that available.

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STUDY AREAS

Cooper's Hawks and Sharp-shinned Hawks were studied in the 26 km^2 Squaw Peak study area located 10 km northeast of Provo, Utah Co., in the Uinta National Forest. Elevation ranged from 3350 m at the summit of Cascade Mountain at the east edge of the study area, to a low point of 1370 m where the Provo river crossed the north end of the study area. Nests of pairs studied were no higher in elevation than 2350 m. Vegetation type varied greatly with elevation and slope aspect. Dominant tree species, ordered roughly from low to high elevation, were: Gambel's oak (Quercus gambelli), big-toothed maple (Acer grandidentatum), white fir (Abies concolor), Rocky Mountain Douglas fir (Pseudotsuga menziesii), quaking aspen (Populus

tremuloides), spruce (Picea sp.) and sub-alpine fir (Abies lasiocarpa). Riparian woodland containing cottonwoods (Populus spp.) and box elder (Acer negundo) occurred along the Provo River and in isolated pockets along several small tributaries emanating from the south end of the study area.

Cooper's Hawks and Northern Goshawks were studied in the 16 km^2 Sundance study area located 35 km NE of Provo on the east slope of Mt. Timpanogos. Elevation ranged from 1830 - 3585 m. Tree species were similar to those listed for the Squaw Peak area; however the Sundance area contained more extensive stands of conifers and mature stands of aspen. The amount of woodland edge was artificially high due to develpment of the southern third of the study area into a ski resort area.

METHODS

Nest Searches

Systematic ground searches for Accipiter nest sites were conducted prior to leaf-out of deciduous trees in April and May. All habitat types in each study area were searched. Nests located were plotted on 7.5 min topographic maps and checked for occupancy several times each season.

Radio-telemetry Methods

Birds were trapped near their nests in small mist nets using a live Great Horned Owl (Bubo virginianus) as a decoy. Single-staged transmitter packages were mounted either on the tail or back as

suggested by Dunstan (1972) and Kenward (1978). Twenty-six hawks were tagged, but usable data were obtained from only 18 (seven A. striatus, nine A cooperii, two A. gentilis).

Radio-monitoring commenced within a few days of tagging of males and with the resumption of hunting in the case of females (females did not leave the nest stand to hunt until young were near fledging age) and continued until batteries failed or the bird left the study area (usually by 1 September). Signals were monitored from fixed receiving stations equipped with a four-element dual-Yagi null/peak antenna system (AVM Instrument Co., Dublin, California) or occasionally from on foot with a four-element Yagi antenna. In 1983, we attempted to determine locations by triangulating directional fixes taken several minutes apart from different locations by a mobile observer. This method proved unreliable because hawks often moved between readings. In subsequent field seasons, two or more radio-trackers manned fixed receiving stations and locations were made by triangulation of directional readings taken simultaneously at each station. Citizen band radios were used for communication between stations. Directional accuracy (95% level) of the null/peak antenna system was tested using beacon transmitters and found to be $\pm$ 1 degree.

The two behavioral sampling methods used were focal animal and scan sampling (Altman 1974). During focal animal samples, the signal of a systematically chosen bird was continually monitored for a 2-h period and the time spent at each location was recorded. Scan samples, which consisted of near simultaneous directional

readings on all birds in the study area, were taken at hourly intervals.

Measurement of Nesting Habitat

Sixteen habitat variables were measured following methods adapted from James and Shugart (1970), Reynolds et al. (1982) and Moore and Henny (1983). Variables measured were percent slope, tree diameter at breast height (dbh), tree (stems $\geq$ 5 cm dbh) density, tree height, canopy height, crown depth, canopy cover (as measured with occular tube from 20 pts), percent frequency of coniferous trees, shrub cover index (scale of 1-5), herbaceous cover index (scale of 1-10), site aspect, nest directional exposure, nest height, nest tree height, nest tree dbh, and height of nest relative to canopy base. Tree density and percent frequency of conifer trees were determined by counting trees within a 15.4-m (50 ft) radius of the nest tree. Tree diameter and tree height were measured for the nest tree and 12 other trees selected via the point-centered quarter method. The three points used were the center of the nest tree and 10 m away along two cardinal compass directions chosen by toss of a coin. Canopy height and canopy depth were measured at five points, one at the nest tree and the others 10 m away along each of the four cardinal directions. Each nest or nest site was treated as a single observation and species means were compared. The first 10 variables listed above (those describing the characteristics of the entire nest stand) were entered into a stepwise, discriminant function analysis to determine

which variables were most important in distinguishing interspecific differences in nesting habitat.

Data Analysis

Habitat use was investigated by assigning each bird location to one of six habitat classes (ordered roughly from low to high elevation): (1) riparian woodland, (2) low oak shrubland/grassland, (3) oak-maple scrub forest, (4) aspen-maple forest, (5) white fir-Douglas fir forest (to include some mixed conifer and aspen stands) and (6) open montane slopes (to include cliffs, talus slopes, ski trails, avalanche zones and open stands of subalpine fir). Use of each habitat type was determined from two independent data bases: (1) the amount of time spent in each habitat, and (2) the number of bird locations recorded in each habitat. The first method utilized data obtained during focal animal samples. The second method used locations obtained during scan samples and locations made 30 min or more apart (to assure statistical independence) during focal animal samples. Because of the triangulation errors experienced in 1983, only visually-confirmed locations from this season were analyzed. A chi-square analysis was used to test the null hypothesis that use was proportional to availablity, where availability of a given habitat type was calculated as the proportion of that type present within the individual's home range (defined here as the minimum convex polygon enclosing all locations, Mohr 1947). Availability values were obtained by superimposing home ranges onto habitat maps and

determining the relative proportions with a planimeter. If the null hypothesis was rejected, Bonferroni 95% confidence intervals were calculated for each habitat use value to determine which specific types were used more and less than expected (Neu et al. 1974).

RESULTS

Foraging Habitat

Use of habitat for foraging was investigated in seven Sharp-shinned Hawks (four male, three female), nine Cooper's Hawks (five male, four female) and two Northern Goshawks (one of each sex). Relative use and availability of each habitat type for each species (calculated by weighting within species samples equally) are presented in Figure 1. In nearly all cases, use determined by the proportion of time spent in the habitat mirrored that determined by the proportion of locations recorded. Regardless of the method used to calculate relative use, Cooper's Hawks and Northern Goshawks used available habitat non-randomly ($\underline{x}^2 = 95.5$ for location data, and $\underline{x}^2 = 157.7$ for time data, df = 5, $\underline{P} < 0.01$ for Coopers Hawk; $\underline{x}^2 = 109.1$ for location data, df = 5, $\underline{P} < 0.01$ for Northern Goshawk); whereas, use of habitat by Sharp-shinned Hawks was not different from that available ($\underline{x}^2 = 9.9$ for location data, $\underline{x}^2 = 7.9$ for time data, df = 5, $\underline{P} > 0.05$).

Species differed in the habitat types they preferred (used significantly more than expected) and avoided (used significantly less than expected) when foraging (Fig. 2). Northern Goshawks

showed a strong preference for white fir-Douglas fir woodland, even though the nests of the individuals studied were in a pure stand of aspen. They avoided oak-maple woods and open montane slopes. No oak shrubland/grassland areas were present in their home ranges. Cooper's Hawks preferred oak-maple woodland and oak shrubland/grassland and avoided aspen-maple woodland and open montane slopes. Sharp-shinned Hawks showed no significant preference or avoidance of any habitat types. The greatest tendencies noted in this species were high use of riparian woodland and low use of open montane slopes. Although all three species avoided open montane slopes, interpreting this finding is difficult because (1) this was a "catch-all" habitat category, and (2) habitat use calculations were based soley on locations of perched birds, and not areas hunted from the air, or scanned from woodland edge perches. We saw Northern Goshawks and Cooper's Hawks capture prey several times in open areas (ski trails, avalanche zones, etc.) that were adjacent to woodland. It was obvious that these open areas were hunted, even though few radio locations were recorded there.

There was considerable within species variation in the use of habitat types (Table 1). For example, three pairs of Cooper's Hawks were studied in the lower portion of the Squaw Peak area in 1984. Nests were linearly distributed about 700 m apart along a riparian zone and home ranges of each pair contained similar amounts of each habitat type. Of the three males, use by one of oak-maple woodland was significantly greater than expected, a second showed significantly less use of this habitat than expected, while use by

the third was not different than expected. All three males used low oak shrubland/grassland more than expected, but one female used this habitat significantly less than expected. Few consistent patterns of habitat preference or avoidance were evident in the other species as well (Table 1).

We expected hawks to prefer the habitats having the most prey. The prey of Sharp-shinned Hawks was almost exclusively passerine birds (Fischer, unpublished data), as has been found elsewhere (Storer 1966, Reynolds and Meslow 1984). The prey of Cooper's Hawks and Northern Goshawks included appreciable numbers of both birds and small mammals (Fischer, unpublished data) as was previously noted in the Sundance area by Lee (1981). Bird (mostly passerine) densities in the five forest habitats were obtained using variable circular plot censuses (Reynolds et al. 1979) and were as follows: 13.5 birds per hectare in oak shrubland, 15.0 birds per hectare in white fir-Douglas fir forest, 15.4 birds per hectare in oak-maple forest, 16.1 birds per hectare in riparian forest and 20.3 birds per hectare in aspen-maple forest. We did not census birds in open montane slopes, but estimate their density there was lower than any of the other habitat types. The predominant mammalian prey were Uinta ground squirrels (Spermophilus armatus), rock squirrels (S. variagatus) and chipmunks (Eutamius spp., Lee 1981, Fischer, unpublished data). Numbers of small mammals were not quantified but appeared from casual observation to be most abundant in and around clearings in the aspen-maple and oak-maple forests. There was no indication that any of the hawks concentrated foraging

efforts in aspen-maple forest, the habitat which contained the greatest numbers of avian prey, and good numbers of ground squirrels and chipmunks.

Nesting Habitat

Nests of all three species were found in both deciduous and coniferous woodland. For the Northern Goshawk, seven of 10 nests were in white fir-Douglas fir or mixed fir and aspen stands; three were in pure aspen stands. Five of these 10 nests were in aspen trees, five were in fir trees. For the Cooper's Hawk, only one of 17 nests was in coniferous woodland. Nine nests (53%) were in stands of aspen or maple and seven nests (41%) were in riparian woodland comprised of box elder and cottonwood. Five of the 17 nests were in box elder trees, four were in big-toothed maples, two each were in aspen, Gambel's oak and white fir trees, and one each was in a spruce and cottonwood. For the Sharp-shinned Hawk, five (56%) of nine nests were in stands of maples and oaks, three (33%) were in stands of white fir and Douglas Fir, and one (11%) was in an aspen-maple stand. Six of these nests were in firs and one each was in big-toothed maple, Gambel's oak and Utah juniper (Juniperus utahensis).

Vegetative structure of nest sites differed significantly between species of Accipiter (Table 2). Northern Goshawks selected stands with taller, larger-diameter trees and higher and deeper canopies than the other two species. Sharp-shinned Hawks selected stands with shorter, smaller-diameter trees and lower and shallower

canopies than the other species. Cooper's Hawks selected nest stands with a vegetative structure intermediate between the other two species (medium sized trees, medium canopy height and depth). All three species tended to select sites with northerly aspects (Fig. 3). Assuming equal availability of slope aspects, this preference was significant for Accipiter in general ($\chi^2 = 28.7$, df=3, $P < 0.05$). However, our study areas probably contained a disproportionate number of north and east faces. The tendency to select northerly aspects is hardly surprising in central Utah, because well developed forests are largely restricted to this aspect.

Nest and nest tree measurements are summarized in Table 3. Accipiters differed significantly in height of the nest tree, diameter of the nest tree and height of the nest. No difference was evident in placement of the nest relative to canopy height. All three species tended to place nests 2 m or so above the canopy base. This helped conceal the nest from potential predators. The Northern Goshawk was the only species to build nests below the canopy (40% of nests). Nest concealment is probably not as critical to nesting success in this species because it is larger and better able to drive off potential predators. Nests, especially those in conifer trees, were typically placed against the trunk on horizontal branches. No preference in directional exposure of nests (relative to the trunk, Fig. 3) was evident. In each species, nest trees were on average larger than other trees in the stand. In the smaller two species, diameter and height of nest trees (Table 3) averaged

larger than the upper bound of the 95% confidence limits of the respective means for all trees in the stand (Table 2).

Significant differences between species (all combinations) were noted at every step of the discriminant analysis of 10 nest site variables (Table 4). At each step, the variable explaining (by itself) the greatest amount of the among groups variance in the data was entered. Thus, considering each variable alone, tree height (the first variable entered) was the most important variable in the analysis. With all variables entered, nest sites of the three species differed most from one another in tree diameter and canopy depth, as shown by the magnitude of the coefficients of the first two canonical variables (Table 5). The discriminant scores of the first two canonical variables (which accounted for 83.5% and 16.5% respectively of the among species variance) are plotted in Figure 4. A small amount of overlap in nesting habitat occurred between Cooper's Hawk and Sharp-shinned Hawk. No overlap occurred between either of these species and Northern Goshawk. Accuracy of the discriminant functions (canonical variables) was tested with a classification analysis based on posterior probabilities. The classification procedure correctly assigned 88.9% of the nests and misclassified only four nests (Table 6).

DISCUSSION

A bird that pursues prey in the air is probably incapable of exploiting a wooded habitat with vegetation so dense that normal flight is impaired. Presumably, smaller body size and greater

in-flight maneuverability afforded by it, should allow the Sharp-shinned Hawk to use denser woodland than the Cooper's Hawk. Likewise, the Cooper's Hawk should be able to use denser woodland than the Northern Goshawk. It follows that a smaller species should be capable of foraging in a wider range of forest densities than a larger species. Wooded habitats investigated in this study varied from extremely dense oak and oak-maple stands, to moderately dense young aspen stands and riparian woodland, to comparatively open mature aspen and white fir-Douglas fir stands. Sharp-shinned Hawks, the smallest species, foraged in all habitats; Northern Goshawks, the largest species, foraged significantly more often in the more open forest types; thus to a large extent, the use of foraging habitat by Accipiter was consistent with the hypothesis that each species used all habitats it was capable of exploiting. An exception to this pattern was the low use of mature aspen stands by Cooper's Hawks. This might be interpreted as evidence that habitat partitioning occurred between Northern Goshawks (which used mature aspen stands readily) and Cooper's Hawks; however, the individual Cooper's Hawks which showed significant avoidance of aspen stands (1983 sample, Table 1), inhabited the Squaw Peak study area, where breeding Northern Goshawks were lacking.

The low use of aspen stands by Cooper's Hawks was certainly not related to a lack of prey there; this habitat held the most prey. Although our information on prey densities was limited, relative use of the six habitat types appeared unrelated to their respective prey abundances. This may mean food was not limiting, or that some

other factor, such as differential prey vulnerability between habitats, was operating. Previous observations of high nesting success and survival of last-hatched chicks of Northern Goshawks in the Sundance study area (Lee 1980, 1981), along with similar observations of our own (Fischer, unpublished data) cause us to doubt that accipiters were food-limited.

Reynolds et al. (1982) and Moore and Henny (1983) noted that the physical characteristics of nesting habitat of the three Accipiter species corresponded to different successional stages of conifer forests. In Oregon, Sharp-shinned Hawks used young (40-60 yr old), dense stands; Cooper's Hawks used middle-aged (50-80 yr old), moderately dense stands; Northern Goshawks used mature (80+ yr old), more open stands. In central Utah, differences in nesting habitat corresponded less exactly with successional stage (most communities were fairly stable), but similar differences in physical structure held. Characteristics of nest sites of Northern Goshawks in central Utah matched most closely those reported for eastern Oregon (Reynolds et al. 1982), while Cooper's Hawk sites were most similar to those of northeastern Oregon (Moore and Henny 1983) and northern Utah and southern Idaho (Hennessy 1978). Nest sites of Sharp-shinned Hawks were in denser stands of smaller trees than previously reported. The difference in our Sharp-shinned Hawk sites may be related to their deciduous nature. Higher densities of deciduous trees may be necessary to produce the same amount of nesting cover afforded by a given density of coniferous trees. This may be especially true prior to leaf-out of a deciduous stand.

It was at this time that hawks first occupied sites and constructed nests.

In previous studies of coexisting Accipiter, Northern Goshawk nest sites have been found to be generally distinct from those of other Accipiter, but nest sites of Cooper's Hawk and Sharp-shinned Hawk have been found to overlap broadly in vegetational structure (Hennessy 1978, Reynolds et al. 1982, Moore and Henny 1983). In our study areas, nesting habitat of all three species was distinct. Only twice during nest searches was a nest found that was of a species different from what was expected when we entered the stand. Both instances involved Cooper's Hawk nests, one in a stand more typical of Northern Goshawks, the other in a stand more typical of Sharp-shinned Hawks. These two aberrant Cooper's Hawk sites are easily discerned in Figure 4. Of the three species, Northen Goshawks appeared to have the least variable and Cooper's Hawks the most variable nest sites.

It is clear that Sharp-shinned Hawks and Cooper's Hawks did not nest in all habitat types (forest densities) they were capable of occupying. Instead, they chose the densest stands that their relative body size and flying ability allowed them to use. This was also true of Northern Goshawks; their nest sites were usually in the densest part of the aspen or fir woods used. The result of each species selecting the densest sites possible was a clear segregation between them in nesting habitat.

Partitioning of available resources between closely-related species is often assumed to have evolved to reduce competition

(Cody 1974). The differences in nesting habitat of three species of coexisting Buteo hawks in interior western North America (Schmutz et al. 1980, Janes 1985) may have evolved for this reason. In the case of coexisting Accipiter, we favor a different explanation. By locating their nests in dense stands of small trees, Sharp-shinned Hawks may decrease the probability that their nests will be located and depredated by larger accipiters or other large raptors such as Great Horned Owls. Likewise, nest sites of Cooper's Hawks tended to be in stands too dense to allow easy access to larger hawks or owls. We suggest that partitioning of nesting habitat between the three species of Accipiter where they co-occur is a result of each species independently selecting a site safe from predation. This explains why nesting habitat of Cooper's Hawks in northwestern Oregon (Reynolds et al. 1982) and Maryland (Titus and Mosher 1981), where Northern Goshawks do not co-occur (or are rare), is no different than in areas where Northern Goshawks are present. If competition with Northern Goshawks in sympatry prevents Cooper's Hawks from nesting in more mature stands, they should shift their nesting habitat to include such stands in these allopatric situations. The threat of nest predation probably forces each Accipiter to nest in the densest stands possible. Thus, since body size differs between species, optimal nesting habitat for each also differs. This explanation predicts that in the absence of nest predators (especially Great Horned Owls), nest site selection by the smaller species of Accipiter should be more variable.

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Table 1. Habitat use patterns for individual birds. A G indicates use significantly greater than expected; an L indicates use significantly less than expected; a - indicates use not significantly different than expected.

			Habitat Types[1]					
Species[2] and Sex[3]	Bird #	N Loc[4]	R	O-G	O-M	A-M	WF-DF	OMS
SSH-b	1983[5]	49	G	-	-	-	-	-
SSH-m	347	68	-	G	L	-	-	-
SSH-f	363	54	-	-	-	-	-	-
CH-b	1983[6]	38	-	-	G	L	-	-
CH-m	401	119	-	G	L	-	-	-
CH-m	437	112	-	G	G	-	-	L
CH-m	537	117	-	G	-	-	-	L
CH-f	464	69	-	L	G	-	-	-
CH-f	486	24	-	-	-	-	-	-
NG-m	077	154	-	-	L	-	G	L
NG-f	097	88	-	-	-	-	-	-

[1]R = riparian woodland, O-G = oak-grassland, O-M = oak-maple forest, A-M = aspen-maple forest, WF-DF = white fir-Douglas fir forest,

OMS = open montane slopes (includes cliffs, tallus slopes, mountain brush, open sub-alpine fir forest).

[2]SSH = Sharp-shinned Hawk, CH = Cooper's Hawk, NG = Northern Goshawk.

[3]m = male, f = female, b = both sexes included in sample.

[4]Number of independent locations (separated by 30 min or more) recorded.

[5]This sample includes lumped data of 5 Sharp-shinned Hawks (3 m, 2 f) radio-tracked in 1983.

[6]This sample includes lumped data of 4 Cooper's Hawks (2 m, 2 f) radio-tracked in 1983.

Table 2. Nest site characteristics of Accipiter in Utah. Data are means and 95% confidence limits of means for 10 habitat variables.

	Northern Goshawk	Cooper's Hawk	Sharp-shinned Hawk
Sample Size (nests)	10	17	9
Variable:			
Slope (%)	20.9 ± 7.6	15.0 ± 4.5	18.7 ± 5.9
Tree density[1]	7.2 ± 1.8	19.0 ± 4.3	40.3 ± 15.9
Tree diameter (cm)	27.5 ± 5.5	14.7 ± 2.6	10.0 ± 1.3
Tree height (m)	16.3 ± 2.7	9.3 ± 1.3	5.8 ± 0.7
Canopy height (m)	8.1 ± 2.2	4.1 ± 0.9	1.9 ± 0.5
Canopy depth (m)	11.6 ± 4.4	7.3 ± 1.3	4.7 ± 1.3
Shrub cover[2]	2.3 ± 0.6	3.2 ± 0.5	4.4 ± 0.6
Herbaceous cover[3]	4.5 ± 2.3	5.1 ± 0.9	4.7 ± 1.3
Canopy Cover (%)	68.4 ± 6.5	83.1 ± 3.6	81.6 ± 7.1
% coniferous	53.6 ± 30.1	6.2 ± 12.4	2.4 ± 2.5

[1]hundreds of trees per hectare.

2scale 0 (low density) - 5 (high density).

[3]scale 0 (low density) - 10 (high density).

Table 3. Nest and nest tree characteristics of *Accipiter* in Utah. Data are means and 95% confidence limits of means.

	Northern Goshawk	Cooper's Hawk	Sharp-shinned Hawk
Sample Sizes (nests)	10	17	9
Variable:			
Nest height (m)	11.3 ± 2.2	7.1 ± 1.1	3.1 ± 0.8
Nest height above canopy base (m)	3.1 ± 4.1	2.4 ± 1.1	1.7 ± 0.9
Nest tree height (m)	22.4 ± 5.4	12.2 ± 2.6	8.5 ± 1.8
Nest tree diameter (cm)	42.9 ± 13.9	25.5 ± 5.1	17.6 ± 3.8

Table 4. Order of entry of nest site variables and resulting species-comparison F-ratios at each step of the discriminant analysis. All F-ratios listed are significant ($P < 0.05$).

Step	Variable	Error degrees of freedom	*striatus* vs. *cooperii*	*cooperii* vs. *gentilis*	*striatus* vs. *gentilis*
1	Tree height	33	10.03	43.16	79.93
2	Canopy cover	32	4.88	33.45	44.13
3	Tree density	31	6.85	21.75	30.43
4	Tree diameter	30	5.77	17.05	22.12
5	Canopy depth	29	4.47	17.02	19.73
6	% slope	28	4.46	13.70	16.68
7	Shrub cover	27	4.10	11.63	14.90
8	Canopy height	26	3.67	10.24	13.54
9	Herbaceous cover	25	3.32	8.95	11.57
10	% coniferous	24	2.88	7.73	10.01

Table 5. Standardized coefficients of the first two discriminant functions[1] (canonical variables) in comparisons of vegetation sampling at *Accipiter* nest sites.

Variable	Discriminant Function 1	Discriminant Function 2
% slope	- 0.16961	0.36364
Tree density	0.19445	0.71754
Tree diameter	0.82006	1.39556
Tree height	0.38434	- 0.32246
Canopy height	0.40941	- 0.19338
Canopy depth	- 0.48064	- 1.22371
Shrub cover	- 0.34148	0.19482
Herbaceous cover	- 0.08372	- 0.39468
Canopy cover	- 0.40340	- 0.54751
% coniferous	- 0.06079	0.12263

[1]Discriminant functions are linear combinations of the 10 habitat variables. The first function accounted for 83.5% of the among groups (species) variance; the second function accounted for the remaining 16.5% of the variance. Coefficients provide a relative measure of the importance of each variable in distinguishing nest sites of each *Accipiter*.

Table 6. Classification results of the discriminant analysis.

Actual species	Number of nest sites	Predicted species membership		
		striatus	*cooperii*	*gentilis*
Sharp-shinned Hawk (*A. striatus*)	9	7 77.8%	2 22.2%	0 0.0%
Cooper's Hawk (*A. cooperii*)	17	1 5.9%	15 88.2%	1 5.9%
Northern Goshawk (*A. gentilis*)	10	0 0.0%	0 0.0%	10 100.0%

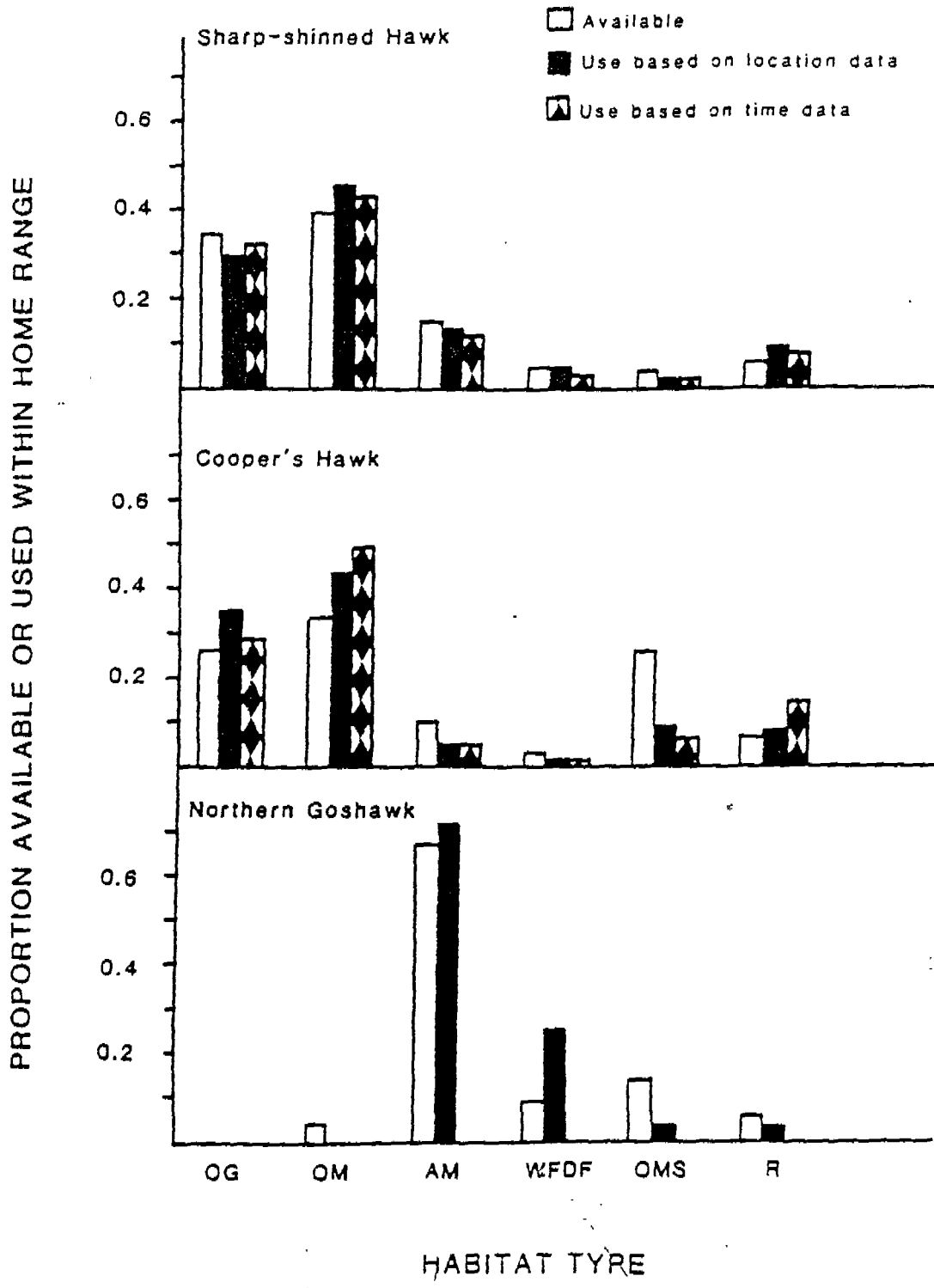
Figure Captions:

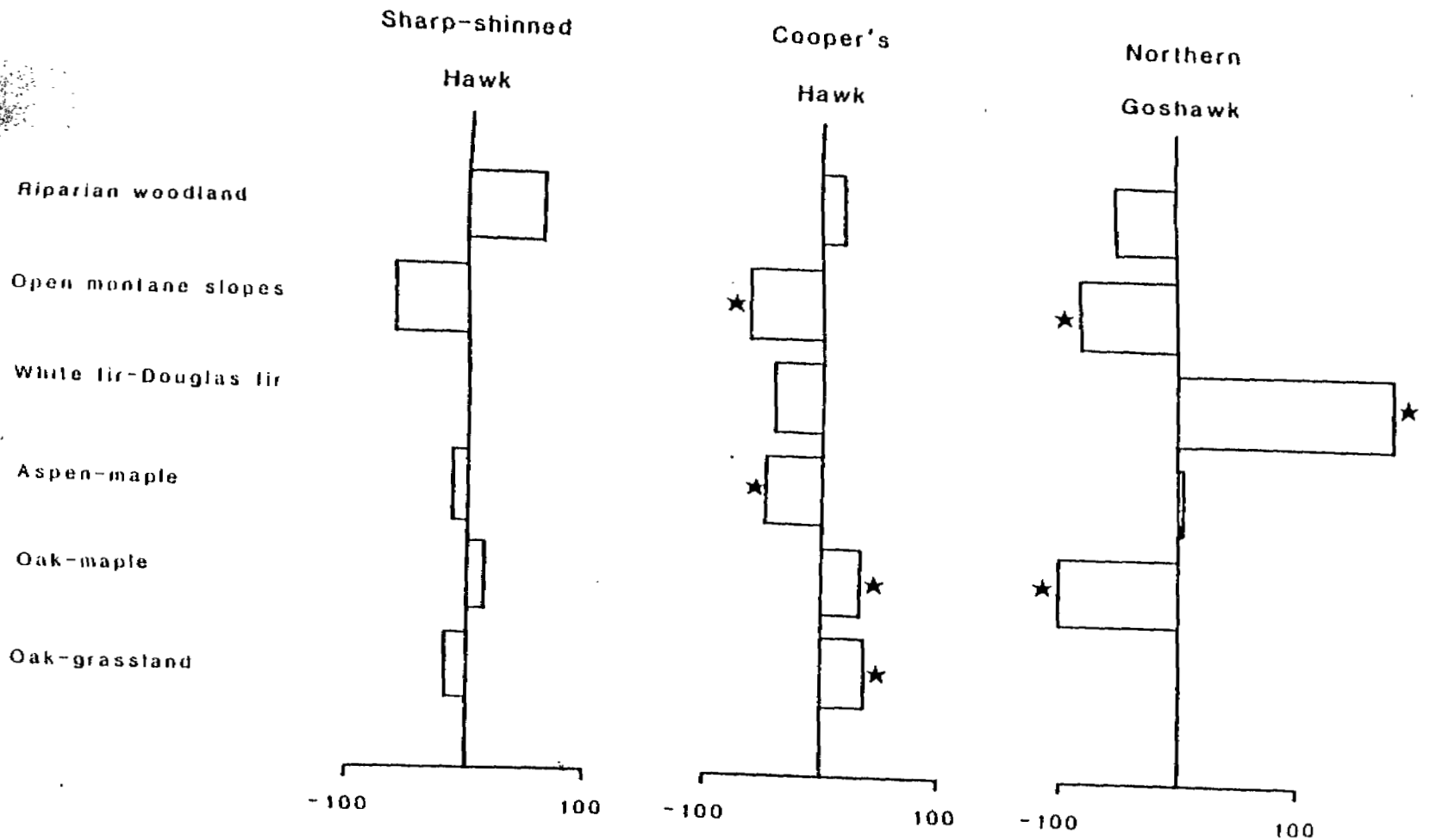
Figure 1. Habitat available and used by foraging accipiters in Utah. Two measures of habitat use, proportion of locations recorded and time spent in each habitat type, are presented. Sample sizes were as follows: 7 hawks, 171 locations, 694 min for Sharp-shinned Hawk; 9 hawks, 479 locations, 2288 min for Cooper's Hawk; 2 hawks, 242 locations for Northern Goshawk. For Cooper's Hawks and Northern Goshawks, use was significantly different from that expected based on availability

Figure 2. Percent deviation from expected use of six habitat types by three species of Accipiter. Only location data are presented. A star denotes a significant deviation based on the test of Neu et al. (1974). Sample sizes same as in Fig. 1.

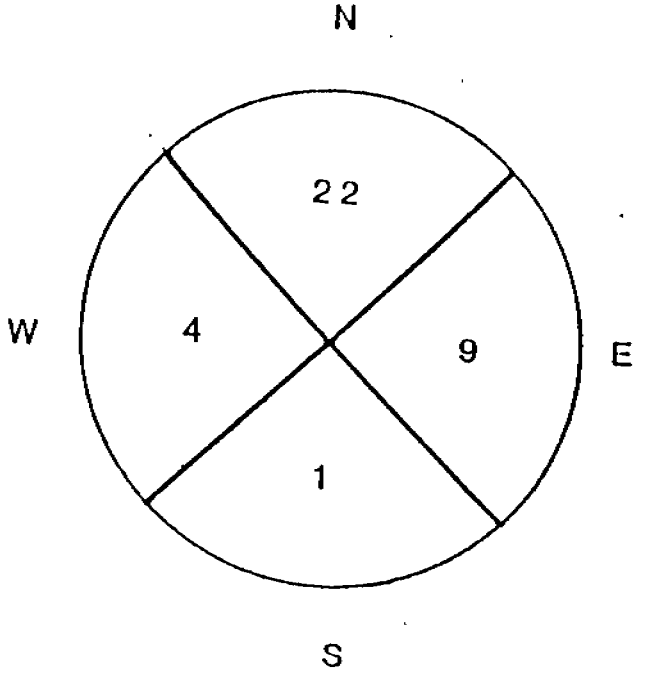
Figure 3. Directional exposure of nest sites and nests of Accipiter hawks. Number in each cell is the number of sites or nests with that exposure. The central cell in B represents nests built in the crotch of the main stem, rather than against side of trunk.

Figure 4. Plot of the first two discriminant function (DF) scores for 36 nest sites of Accipiter in Utah. Squares are Northern Goshawk (NG) sites; small asterisks are Cooper's Hawk (CH) sites; circles are Sharp-shinned Hawk (SSH) sites. Large asterisks are group centroids.


Available
Use based on location data
Use based on time data
Sharp-shinned Hawk
Cooper's Hawk
Northern Goshawk
0.6
0.4
0.2
PROPORTION AVAILABLE OR USED WITHIN HOME RANGE
OG
OM
AM
WFDF
OMS
R
HABITAT TYRE


Sharp-shinned Hawk
Cooper's Hawk
Northern Goshawk
Riparian woodland
Open montane slopes
White fir-Douglas fir
Aspen-maple
Oak-maple
Oak-grassland
-100
100
-100
100
-100
100
% DEVIATION FROM EXPECTED USE

A. SITES



B. NESTS